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# THE USE OF ERTS IMAGERY IN RESERVOIR MANAGEMENT AND OPERATION

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16. Abstract Studies at NED, Corps of Engineers, are focused on evaluating the possible usefulness of ERTS DCS and imagery to its watershed management functions. The first six months of ERTS-1 have been devoted primarily to installing and debugging equipment and general familiarization with ERTS data products, both DCS and imagery. To date 17 of a planned 27 data collection platforms have been installed and are reporting to NED various hydrometeorological parameters on a near real-time basis via a direct teletype link with GSFC. Only a very preliminary study of the data has been made so far. Statistical tests will be applied as soon as the data bank is of sufficient proportion. This should be within a few months as installation of the remaining DCP's is expected to be accomplished by early spring. Our imagery studies are centering on both photo-interpretation and computer-oriented analyses for depictions of useful hydrologic features. Preliminary work has suggested that configuration and areal coverage of surface waters, as well as other hydrologically related terrain features, may be obtained from ERTS imagery to an extent that would be useful to NED. Computer-oriented pattern recognition techniques are being developed to help automate the identification and analysis of hydrologic features in the imagery. Emphasis is made upon the need for close man-machine interaction while training the computer for these tasks.

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# PREFACE

The New England Division, Corps of Engineers, is participating in the ERTS-1 experiment to assess the possible usefulness of satellites such as ERTS in the fulfillment of its watershed management functions. We are studying both DCS and imagery in this regard. Our DCS studies encompass two separate goals: one -- to determine the viability of satellites for the relay of real-time hydrometeorological data for watershed management purposes, and the other -- to aid in the selection of the most economically feasible and technically useful layout of data collection points to provide all the necessary information for the optimal regulation of a river basin. Our imagery studies are focused on the evaluation of the ability of ERTS imagery to provide useful and timely supplementary hydrologic information. Our work has been centered on both photo-interpretation and computer-oriented analyses of the imagery.

To date, only very preliminary analyses have been made of the ERTS data-products, both DCS and imagery. During the first six months of our participation in ERTS we have been mainly concerned with installing and debugging equipment and familiarizing ourselves with the data-products.

As of 31 December, 17 of a planned 27 DCP's had been installed and were reporting to NED various hydrometeorological parameters on a near real-time basis via a direct teletype link with Goddard Space Flight Center. Statistical tests will be applied as soon as the data bank is of sufficient proportion. This should be within a few months as installation of remaining DCP's is expected to be accomplished by early spring.

Preliminary analysis of ERTS imagery suggests that the configuration and areal coverage of surface waters, as well as other hydrologically related terrain features, may be obtained from ERTS imagery to an extent that would be useful to NED. Computer-oriented pattern recognition techniques are being developed to help automate the identification and analysis of hydrologic features. Considerable man-machine interaction is required while training the computer for these tasks.

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# 1.0 INTRODUCTION

The purpose of this report is to summarize the first six months of our participation in the ERTS-1 program and to report in detail the progress of our study since our last report, dated 26 October 1972.

The imagery analysis and imagery/DCS interaction portions of our investigation are subcontracted to the University of Connecticut (UCONN) at Storrs, under the direction of Dr. Paul Bock. This contract extends from 1 July 1972 through 3 September 1973. In certain aspects of the DCS segment of our studies we are also cooperating with Dr. Duwayne Anderson, Dr. Harlan McKim and Ray Tuinstra of the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL), Hanover, New Hampshire. During the first six months of ERTS-1, personnel from these organizations attended several working group meetings and one major meeting on 3 October 1972 at the University of Connecticut.

The period since the launch of ERTS-1 has been devoted to overcoming problems associated with late delivery of equipment and supplies, installing equipment, obtaining timely data products, debugging the system and establishing DCS data and imagery filing and retrieval systems rather than performing extensive research. To date, 17 data collection platforms have been installed and are reporting various hydrometeorological parameters on a near real-time basis to NED, Corps of Engineers in Waltham, Massachusetts. Only very preliminary analyses have been made upon these data. ERTS imagery has been used primarily as a training tool in order to become familiar with the characteristics of the imagery products with a goal toward delineating the specific plan of data analysis (see updated Data Analysis Plan dated 8 November 1972).

The body of this report will be divided between our DCS studies and those involving ERTS imagery and imagery/DCS interactions.

## 2.0 DCS STUDIES

### 2.1 BACKGROUND

As described in detail in our updated data analysis plan, the DCS studies involve two separate goals. The one -- to determine the viability of satellites such as ERTS for the relay of real-time hydrometeorological data for watershed management purposes, and the other -- to aid in the selection of the most economically feasible and technically useful layout of data collection points to provide all the necessary information for the optimal regulation of a river basin.

### 2.2 SUMMARY OF PROGRESS

#### 2.2.1 Introduction

Location of operating DCP's and proposed sites for future installation are included in the table on page 15. The two DCP's operated by CRREL will test various soil temperature, soil moisture and other environmental sensors. The platform at the University of Connecticut is a spare and will be used intermittently to test interfacing techniques.

We are receiving DCS data via a real-time teletype link with Goddard Space Flight Center (GSFC) which was installed on 16 November 1972. This data is being acquired as a printout and also on punched tape for transferral to computer files. We are continuing to receive punchcards and printouts by mail from GSFC for purposes of link error evaluation.

#### 2.2.2 DCP Installation, Maintenance and Performance

The following paragraphs describe in detail the progress and problems involved in setting up our ERTS DCP system. We had hoped to have a system of 27 DCP's installed within six months after the launch of ERTS-1. Instead we have only the 17 already mentioned, due primarily to the many unforeseen problems in obtaining DCP's, interfaces and peripheral equipment.

By the end of September 1972, only 12 DCP's had been shipped to NED and, of these, 8 were installed and properly operating, one was being tested and 3 were inoperable. At our test site in Waltham, two of these latter DCP's were damaged due to a lack of proper grounding. The third DCP (#6220) failed at a river gaging station after 2 months of operation. A few days after this failure, General Electric (GE) advised us that a unipoint ground should be installed between the batteries of the DCP and the sensor. This is now part of our installation procedure. It is not known whether the failure to platform #6220 was due to the lack of a unipoint ground.

By the end of December 1972, all 30 DCP's were delivered to NED, and a total of 17 were installed and properly operating. All the peripheral equipment, except a rain gage interface on order from the U.S. Geological Survey (USGS), had been received. Between 1 October and 31 December, two DCP's were removed from the field for repairs. DCP #6246, removed from a river gaging station, had a damaged programmer board, digital board and blown fuse. This DCP operated for 3 months and had damage similar to DCP #6220. The other DCP checked out on the field test set but never transmitted a strong signal. The trouble was found to be a bad integrated circuit identified as U22 in Fig. 6-3, page 6-47/48 of the depot manual. All DCP's are now tested for 24 hours in Waltham before field deployment. A simple inexpensive field strength meter acquired from General Electric has proved to be invaluable in testing and trouble shooting. The field strength meter is used both at the Waltham test site and at field installations. By this method we have readily found several antenna cables with weak connections that came apart during field installation. DCP maintenance, in general, is a continuing problem, but the situation is improving as we become more familiar with the equipment. Personnel from CRREL are handling most of the trouble shooting and repair work and have reached a level of expertise where contact with G.E. is rare.

With the installation of the system more than half complete, we are now devoting more time to analyzing the overall operation. Several platforms have been in operation for more than three months. Of particular interest to us are useful battery life, environmental effects and sensor performance. The "Gel-Cell" batteries are still performing satisfactorily. We are now in the winter season and severe weather conditions have had no adverse effect on the system up to this date. The reliability of many new sensors and interfaces has not been satisfactory. At 3 of the river gaging stations, data received has not been valid. In all these cases, the sensor is the new Leupold & Stevens digital recording unit with a telemetry harness (so-called encoding module). We suspect the trouble to be in the encoding module. All of the water quality stations are installed but the data received has been erratic. We suspect the problem to be within the new Bristol "Datamaster" which stores the sensor information.

### 2.2.3 DCS Data Acquisition and Storage

Transfer of data from NASA to NED has improved markedly since our last report. Punchcards and printouts are received within a week after the acquisition of the data at GSFC. The near real-time teletype link with NASA has been functioning well, with about a 45 minute interval between ERTS-1 passover and data reception at NED.

All DCS data via paper tape from the real-time link and the punchcards received by mail from NASA is being stored in our computer. Ground truth is also being entered by punchcards. We are still in the process of assessing the feasibility and costs for setting up a computer data link between the NED and the University of Connecticut.

### 2.2.4 DCS Studies, Program for Next Reporting Interval and Conclusions

Only very preliminary study has been made of the data so far, due to the problems of equipment acquisition and installation which have delayed the establishment of a DCS network sizeable enough for analysis. Statistical tests that have been studied and selected, and computer programs written for data analysis will be applied as soon as the data bank is of sufficient proportion. This should be within a few months, as installation of the remaining DCP's is anticipated by early spring.

## 3.0 IMAGERY AND IMAGERY/DCS INTERACTION STUDIES

### 3.1 BACKGROUND

Work is underway to evaluate the application of ERTS imagery to provide useful and timely hydrologic information for NED Reservoir Control Center (RCC) management purposes. The overall plan of study is described in a Service Contract between NED and the University of Connecticut for NASA-ERTS Imagery Study, dated 30 June 1972.

The initial six months can be characterized as a "start-up" phase leading into preliminary analyses of ERTS imagery. The main efforts focused on adequate staffing (including assignment of graduate students); general identification and scoping of tasks (including background review); organizing an efficient system for filing the ERTS imagery; solving "housekeeping" problems such as setting up laboratory space and equipment, obtaining reports, maps (particularly important for the New England area) and other information; visiting selected watersheds; liaison with NED RCC personnel to become familiar with operational missions and problems; becoming acquanited with the NED METS and DCP data collection systems; and meeting with other Federal agencies (USGS, NOAA, etc.). Imagery receipt from NASA has been attended by considerable time delays, frequently as much as a one-month lag from date of the image itself. These delays continue as of this report.

The analysis of the ERTS imagery is directed toward development of operational benefits derived from improved NED operations rather than to "research" objectives per se. The thrust of the study is to integrate interpretations of the imagery analysis, the DCS information, the METS data and other conventional sources of information -- all to provide an improved information base for the timely reservoir management decisions of the NED RCC.

During this initial six-month period we have literally only "scratched the surface" of potential imagery applications to the complex operations of NED RCC. What is reported here is only the first sampling of the ERTS imagery.

As far as we know this effort represents the first attempt at the operational (or near operational) use of real ERTS imagery for purposes of managing a vast and complicated multistructure, multipurpose reservoir control system ($300 million system of 35 reservoirs, 34 local protection projects, 4 hurricane barriers located in five major basins in New England). Further analyses using more ERTS data are expected to give significant results because: our experience base is growing in ERTS/NED operational problems; of availability of four seasons' data (including a complete network of DCP's) and the greater chance of occurrence of significant hydrologic events such as floods; of better interpretation techniques (imagery and computer-oriented).

Work is proceeding generally along two lines: (a) evaluation of MSS frames (and RBV frames when available) in all bands (and in color when available) and (b) use and development of computer-oriented pattern recognition techniques to assist the interpretation and use of the imagery.

For reporting purposes, Imagery and Imagery/DCS Interaction Studies are divided into two main sections: Imagery-Photo Interpretation and Imagery-Computer-oriented Analyses.

## 3.2 IMAGERY-PHOTO INTERPRETATION

### 3.2.1 Summary of Progress

#### 3.2.1.1 ERTS Photo Products

To date, multiple photo-products of 69 separate images of at least one of every image frame covering all or part of New England have been received at the University of Connecticut. One frame of image sets has been received for as many as five different dates since the launching. New England and its coastal waters are covered in 31 frames taken on five orbital passes corresponding to 5 successive days, the sequence repeating itself every eighteen days. The first series of orbital passes were made during the period 26 July through 30 July 1972 and have been repeated nine times to date. Thus if conditions were perfect New England would presently appear in 9 x 31 = 279 ERTS image frames. Thus the 69 images received so far, minus 4 of coverage completely outside the New England area, indicate that we have received, to date, 23 percent of the possible image sets covering all or part of New England. The balance presumably have not been received because of a backlog in ordering, poor image quality, excessive cloud cover, or other difficulties. Of the images so far received, approximately 35 percent have minimal or no cloud cover and are of high quality, 45 percent have partial cloud cover but are useful and of generally good quality, and the remaining 20 percent have extensive cloud cover and are of limited usefulness. An image library has been established with a filing and catalogue system described in Appendix I. The system is based on orbital coverage with images catalogued by means of a schedule of completed and anticipated ERTS coverage of New England from date of launch through June 1973.

#### 3.2.1.2 Imagery Study

USGS 1/250,000 quadrangle maps covering New England have been ordered and received and are being studied to locate and identify terrain and hydrological features. The present area of concentration is the Merrimack River basin located in northeastern Massachusetts and southern and central New Hampshire.

Considerable "general reconnaissance" of the ERTS imagery are made routinely. In particular we look for relative changes in hydrologic features, including areas of large and small lakes (as indications of volumes of surface storage). The following discussion provides examples of hydrologic change detection.

ERTS Imagery: Frames E-1024-15055 and 1024-15062, date of orbit 16 August 72; and frames E-1096-15063 and E-1096-15065, date of orbit 27 October 72.

Corresponding USGS 1/250,000 quadrangle coverage: NK 19-1 and NK 19-10, upper and western Merrimack River Watershed-White Mountain, Lake Winnipesaukee, Concord-Manchester, New Hampshire area.

The overall pattern of surface waters appear much the same in both sets of photos taken on different dates. The large lakes appear relatively unchanged from 16 August to 27 October. Some smaller lakes and ponds and portions of the Merrimack River, especially noticeable in the vicinity of Concord and the stretch between Concord and Manchester, New Hampshire, appear swollen in image E-1096-15065 (27 Oct) compared to the same location in image E-1024-15062 (16 Aug). These observations (and others) do suggest the possibility that actual flood patterns at different stages may be determined with some accuracy and that the imagery may be useful in checking expected flood patterns along the length of rivers against the flood configuration that actually occurred.

As expected, delineation of hydrological features appears best in the near-infrared bands (RBV-3 or MSS-6 & 7). Water appears to completely absorb near-infrared radiation regardless of depth and appears black in all photos in bands MSS-6 & 7. Some waters do appear in different shadings in the lower MSS-4 & 5 bands of visible light. (Note different shadings in band MSS-4, Image E-1096-15063, Lake Memphremagog, and also along Merrimack and Connecticut Rivers in this image and E-1096-15065). Causes for these apparent differing rates of absorption have not been determined. Depth and quality may be factors.

For the most part, configurations of surface waters in imagery, especially those of larger lakes, correspond well to their counterparts on USGS quadrangle maps. Some smaller bodies on the maps in the Merrimack basin region exhibit slight distortions from their configurations as they appear on ERTS imagery (e.g., several small lakes south of Lake Winnepesaukee, New Hampshire). The Blackwater flood control reservoir also appears on the quadrangle map in a different configuration than on imagery. This is expected since most maps show flood control reservoirs at full capacity although these are rarely in this condition. The images may well be of value in showing actual reservoir surface configurations at various known stages.

Terrain features show up much better in the red-infrared bands of later images, dated 27 October, when most of the green vegetation has disappeared. Green vegetation, prevalent in the 16 August images, seems to exhibit a high reflectance and diffusion of infrared, thus obscuring terrain features in these earlier images. Metropolitan areas with little vegetative cover seem to absorb red-infrared and thus show up very distinctly as dark areas in the MSS-6 & 7 bands of various images (e.g., Concord and Manchester, New Hampshire and Worcester, Massachusetts in aforementioned images). The correlation between different levels of absorption and various surface water runoff characteristics will be investigated. An attempt is also being made to delineate actual watershed boundaries using visible terrain features in the imagery such as ridgelines, hill and mountain tops, saddle points and valleys. Location of drainage divides is an important preliminary step in watershed analysis.

### 3.2.1.3 Equipment

To date, we have acquired several pieces of lighting equipment for viewing transparencies and we are presently constructing smaller, portable light tables.

One of the purposes of the early studies has been to determine what additional equipment will be needed for more detailed study in the course of investigation. Brochures and pamphlets from several manufacturers of photogrammetric and photo-interpretation equipment, useful for ERTS imagery investigation, have been reviewed. Requirements so far seem to dictate the necessity for magnification, measuring and drafting equipment for use in conjunction with selected ERTS imagery products. Some types of add-color devices using various color filters of the type advertised in the several technical brochures for forming color and false color images have been investigated. No conclusions regarding equipment have been reached. If color images are required, they will be ordered from NASA, or arrangements will be made for darkroom reproduction from transparencies on hand.

### 3.2.1.4 Auxiliary Information Including DCS

Arrangements are being made for NED to transfer to UCONN on a regular basis the DCS and METS data to be used in conjunction with the study of ERTS imagery. The USGS offices in both Hartford and Boston have been contacted for receipt of available watershed surveys, reports and other information. Arrangements are also being made with the River Forecast Center office in Hartford and local weather station at Storrs for receipt of weather, precipitation and snow accumulation charts and data.

DCP's provide point information of precipitation, river stage (can be converted to discharge), water quality parameters, and tides and winds. These DCP data together with METS data of river stage and precipitation form the major source of time-dependent ground truth information for interpretation of the ERTS imagery.

Snow information is obtained from snow survey networks operated by NED, Massachusetts Water Resources Commission, USGS and other agencies. "Snow Bulletins" issued by NED during the winter and spring provide graphs and maps of water equivalent of snow in inches for the various basins in New England.

3.2.2 Program for Next Reporting Interval

a. Build up imagery library to include suitable scenes for all four seasons.

b. Build up local information sources to include: weekly climatological data and daily weather maps corresponding to period and location of imagery, ERTS DCS and METS data corresponding to imagery, flood maps, snow charts and results of fieldwork associated with interpretation of ERTS imagery.

c. Imagery-Photo Interpretation

(1) Quantitative measurement of hydrologic changes to include plotting and planimetering of surface waters as well as changes in image intensity in conjunction with computer maps.

(2) Attempts to correlate imagery features and shadings with terrain type and characteristics leading to possible usefulness in establishing area and extent of terrain with various hydrologic properties such as runoff and drainage characteristics, soil moisture retention, etc.

(3) Attempts to determine some of the in-water characteristics which, to date, have shown up as different shadings in some waters in imagery in the lower visible bands (MSS-4 & 5).

(4) Determination of extent, area and configuration of snow coverage as well as investigation of possible changes in snow conditions corresponding to different radiation absorption levels.

(5) Updating of important map information noting especially changes in reservoir extent, area and configuration with changes in stage.

### 3.2.3 Conclusions

Imagery Observations:

a. IR bands (RBV3 and MSS-7) show best the delineation of surface water boundaries. These bands are satisfactory by themselves for plotting and measuring surface areas, extent, and configurations of surface waters. As expected, near-IR does not, however, appear to indicate other characteristics such as depth, temperature or water quality.

b. Changes in extent and surface areas of water bodies are observable between the times at which images of a given location have been taken. Precise measurements will be made in the next phase.

c. No conclusions have been made about the observability of soil moisture as related to NED purposes.

d. Hydrologic features appear in considerable detail and provide an excellent check to update USGS quadrangle maps. This is important in hydrologic investigation.

e. Urban centers are well-defined especially in band MSS-7. This may be useful in determining updated estimates of extent of high flood-damage areas.

## 3.3 IMAGERY COMPUTER-ORIENTED ANALYSIS

### 3.3.1 Introduction

During the first stages of the ERTS-1 imagery study, and while we were waiting for data to arrive, most work was directed towards background research. Literature (see references 1-12) in the field of remote sensing, including the ERTS material in particular and its relationships to missions of the NED RCC, has been obtained and studied. We took particular interest in the field of computer analysis of imagery.

Various computer-oriented image-processing techniques are now being applied to the ERTS magnetic tapes. In order to use these techniques operationally, ground truth information about the hydrologic events (i.e., snow conditions, flooding, rain data, etc.) must be established in relation to the imagery obtained. This kind of information is needed to "train" the computer in recognizing and analyzing the hydrologic events in the ERTS imagery. We are beginning to organize this ground truth information as we continue to develop our techniques for computer analysis. A summary of the digital image-processing activities in remote sensing for earth resources may be found in a report by Nagy (12).

### 3.3.2 Summary of Progress

#### 3.3.2.1 Initial Stages

Contacts were made with groups of ERTS investigators who have been developing programs to perform automatic classification on land uses and agricultural crops, and others who have been doing work in flood analysis and control (1, 3, 7). Some of these researchers have replied, and the information they sent is being analyzed for possible applications.

Progress has been delayed somewhat due to a NASA backlog in orders of computer data. With the assistance of NASA-Goddard, several problems concerning format and content-specification for the computer compatible-tapes have been solved, and work has begun on the actual processing of these tapes. This is described in the following sections.

#### 3.3.2.2 Preliminary Analysis

The first computer program, currently being developed, prints sections of an ERTS image at a particular band using a pseudo gray scale of blank to full characters. These sections are also printed in a numerative scale, so outlines and boundaries may be ascertained accurately. The user is able to select any portions of the image for printout so as to assist his interpretation studies. A description of the print program is given in Appendix II. It is hoped that this work will also give those involved in the same type of interpretation studies a better feel for the data. An interaction of human photo interpretation and computer data handling will be used at this point to print out in detail "closeups" of particular hydrologic features, such as lakes and rivers. Using these techniques, the drainage basins of the Merrimack River and the Connecticut River will be studied.

#### 3.3.2.3 Location of Image Features within the Computer System

Work is underway to develop a data handling package which performs an image feature search. Within the image, it is often desirable to have the computer identify, store and later retrieve such hydrologic features as snow cover, bodies of water, clouds, etc. This will require application of numerical pattern recognition schemes. These schemes in general deal with the problem of programming a computer (or any other device) to automatically classify data points into one of several known categories. Each of these categories could be one of the hydrologic events within an ERTS image.

### 3.3.3 Programs for the Next Reporting Interval

#### 3.3.3.1 Further Analysis

The specific objective will be to develop computer-based procedures that will be capable of identifying and analyzing the various hydrologic events that are considered relevant to NED flood control and prediction operations. Emphasis will be placed on experimental use of computerized pattern-recognition techniques in NED Reservoir Control Center operating procedures and as inputs to mathematical models of the Merrimack River and other hydrologic phenomena. Since a large amount of imagery data is involved, it will be necessary to extract certain "features" present (along the same lines, only in greater detail, as the features mentioned in the previous section). Once a reduced feature subset of the imagery data has been identified it will be stored and processed with a more efficient data handling scheme. This process of feature identification may be properly called data reduction. These studies will have to be correlated with those at NED RCC. ERTS-relayed and other ground truth data will have to be collected to "train" the computer in automatic identification and analysis of the desired features. We plan a systematic interaction to determine how the results of computer analysis at UCONN can be used to refine or improve the predictive models used at NED.

#### 3.3.3.2 Long-Range Goals

Further analysis will be planned to investigate new means for the automatic interpretation of ERTS imagery that are relevant to NED missions. Possible topics for investigation include:

a. Dynamic analysis of ERTS imagery, to determine changes in hydrologic condition with respect to time and space to aid in long-range flood control and NED predictive missions. This is an overriding feature in the day to day operations of NED RCC where rapidly changing hydrologic conditions must be monitored, interpreted and reservoir management operations quickly put into effect.

b. Refinement of evaluation of flood damages and identification of flooded areas in post-flood analysis is an area of high concern to NED. In particular, methods for damage estimation from minor floods seem inadequate, although the cumulative damages would appear to warrant rapid updated flood survey data.

c. Updating and refinement of mapping flood plain areas on a regional basis. The Corps of Engineers is responsible for preparing flood plain information studies.

d. Mathematical simulation of imagery-derived data for assessing combined effects of storms and NED operating rules on reservoirs and riverflows. Such use of ERTS data would assist NED in-house studies for reservoir regulation manuals.

e. The means for optimally combining information extracted from separate RBV and MSS bands.

f. The determination of the effects of the imagery overlap on the ability of machine analysis of the ERTS imagery.

### 3.3.4 Conclusions

At this time, several tentative conclusions may be drawn as a result of the first stages of the ERTS Imagery Computer-oriented Analysis Study. They are as follows:

a. There is clearly a need to apply computer-oriented pattern recognition techniques to perform detailed analysis of the ERTS imagery. Of particular importance are those techniques that will allow us to detect shade boundaries and recognize geometrical features relevant to the hydrological events in the imagery. Special care must be exercised in applying these techniques so that only minimum human assistance is needed after the initial training period.

b. The initial cost of computer processing the imagery is rather high (about $9/quarter frame/spectral band). This is due to the fact that large amounts of data are involved in each frame and considerable experimentation with the data is necessary to refine the analysis schemes. To reduce the cost, more efficient methods of data handling are being developed.

c. It is essential to have close man-machine interaction at various stages of the analysis study. This kind of interaction is necessary, not only for computer-assisted photo interpretation, but particularly important if interpretation results are to be useful to the missions of NED.

## 4.0 CONTACTS WITH OTHER INVESTIGATORS, ORGANIZATIONS AND THE GENERAL PUBLIC

We are keeping in contact with other ERTS-1 investigators as well as with non-participating individuals, agencies and others who have shown interest in our progress. We are also keeping in close contact with Corps of Engineers Headquarters in Washington and other Corps offices around the country.

Utilizing imagery products received at NED, CRREL evaluated the potential use of ERTS-1 imagery in the recently initiated nation-wide dam inventory and submitted a report directly to the Corps' Washington headquarters.

We have evaluated the possibility of co-hosting a proposed meeting of selected DCS users at Wallops Island, Virginia, and concluded that, due to lack of time and personnel, we cannot undertake such a responsibility at this time.

In November, our DCS activities were filmed for inclusion in NASA's ERTS-1 official film. In the past six months, we have received considerable publicity from the local press, radio and television.

ERTS-1 - DCP INFORMATION SHEET
ARMY CORPS OF ENGINEERS, NEW ENGLAND DIVISION 3 JAN, 1973

| ID NO. | DCP NO. | TYPE | STATION NAME | LAT | LONG | IN-STALLED |
|---|---|---|---|---|---|---|
| 1 | 6170 | S | ST. JOHN RIVER AT FORT KENT, MAINE | 47 15 | 68 35 | 091972 |
| 2 | 6071 | S | PENOBSCOT RIVER AT WEST ENFIELD, MAINE | 45 14 | 68 39 | 092072 |
| 3 | 6021 | S | CARABASSETT RIVER AT NORTH ANSON, MAINE | 44 52 | 69 57 | 100472 |
| 4 | 6304 | S | ANDROSCOGGIN RIVER AT AUBURN, MAINE | 44 04 | 70 12 | 112772 |
| 5 | 6106 | S | SACO RIVER AT CORNISH, MAINE | 43 48 | 70 47 | 112872 |
| 6 | 6206 | S | PEMIGEWASSET RIVER AT PLYMOUTH, N.H. | 43 45 | 71 41 | 112272 |
| 7 | | S | MERRIMACK RIVER AT GOFFS FALLS, N.H. | 42 57 | 71 28 | |
| 8 | | S | SOUHEGAN RIVER AT MERRIMACK, N.H. | 42 51 | 71 31 | |
| 9 | 6356 | S | CHARLES R. AT CHARLES R. VILLAGE, MASS. | 42 15 | 71 15 | 071772 |
| 10 | 6220 | S | TOWN BROOK AT QUINCY, MASS. | 42 15 | 71 00 | 090872 |
| 11 | 6010 | S | PAWTUXET RIVER AT CRANSTON, R.I. | 41 45 | 71 27 | 090672 |
| 12 | 6127 | S | CONNECTICUT RIVER AT HARTFORD, CONN. | 41 46 | 72 40 | 083072 |
| 20 | | P | STINSON MOUNTAIN, N.H. | 43 50 | 71 47 | |
| 21 | 6345 | P | SOUTH MOUNTAIN, N.H. | 42 59 | 71 35 | 120672 |
| 22 | | P | FRANKLIN FALLS DAM, N.H. | 43 28 | 71 40 | |
| 23 | | P | BLACKWATER DAM, N.H. | 43 19 | 71 44 | |
| 24 | | P | MACDOWELL DAM, N.H. | 42 54 | 71 59 | |
| 25 | | P | MANSFIELD HOLLOW DAM, CONNECTICUT | 41 46 | 72 11 | |
| 30 | | C | STAMFORD BARRIER, STAMFORD, CONNECTICUT | 41 02 | 73 32 | |
| 40 | 6254 | Q | ASHUELOT RIVER AT WINCHESTER, N.H. | 42 47 | 72 23 | 121272 |
| 41 | 6142 | QS | NORTH NASHUA RIVER AT FITCHBURG, MASS. | 42 34 | 71 47 | 110672 |
| 42 | 6355 | Q | WESTFIELD R. AT WEST SPRINGFIELD, MASS. | 42 06 | 72 38 | 092872 |
| 43 | 6242 | Q | CHICOPEE RIVER AT CHICOPEE, MASS. | 42 09 | 72 35 | 121472 |
| 50 | 6147 | T | NED HEADQUARTERS, WALTHAM, MASS. | 42 24 | 71 13 | 071772 |
| 51 | 6325 | T | COLD REGIONS LAB AT HANOVER, N.H. | VARIABLE | | |
| 52 | 6216 | T | COLD REGIONS LAB AT HANOVER, N.H. | VARIABLE | | 120572 |
| 53 | 6335 | T | UNIV. OF CONN. AT STORRS, CONN. | VARIABLE | | |

* S-RIVER STAGE
P-PRECIPITATION
C-COASTAL(WIND DIRECTION,VELOCITY AND TIDE)
Q-WATER QUALITY(TEMPERATURE,CONDUCTIVITY,PH AND DISSOLVED OXYGEN)
T-TEST SET(SENSORS VARIABLE)

# Appendix A

## UCONN ERTS Photo-Library

The frames on the attached New England mapsheet delineate the areas and position of coverage of ERTS images as described in the orbital coverage section of the NASA ERTS Data Users Handbook. The dots at the centers of the frames represent the likely image format centers and the lines on which they appear represent the paths of the satellite orbits on successive days. (The nadir trace of the satellite is not necessarily coincident with the format center trace of the images, however they are close enough to be assumed coincident for present purposes.) Although there have been some departures of the format centers in image products received to date from their anticipated positions as shown on the map, the anticipated positions have proved accurate enough for filing and cataloguing purposes.

The letter part of the frame label indicates the orbit and hence the day in the series of orbital coverage days (successive orbits on successive days -- one per day -- see Data Users Handbook, orbital coverage section). The first orbit covered is labeled "E", images E-1 thru E-6 being taken on the first orbit/day as the satellite passes from north to south. Orbit "D" is covered 24 hours later on the second day, taking images D-1 thru D-7 as the satellite passes from north to south. Orbits C, B, and A are likewise covered on the corresponding 3rd, 4th and 5th days thus completing the series of orbital coverage days over the New England area. The series repeats itself 18 days after the start of the previous series; i.e., starts again 13 days after completion of a 5-day series.

Photo storage files are given the same labels as the frames shown on the mapsheet. Each file contains the photo-products of images of the area designated by the particular frame, taken at different periods of orbital coverage (every 18 days if all images taken by the ERTS satellite are received). Thus each file will have images of the same areas of coverage taken at different times.

A schedule has been set up for periods of coverage. The photo-library catalogue pages are labeled in the same manner as the frames on the mapsheet and the storage files. Each page of the catalogue contains the dates of expected orbital passes on which the area designated by the frame having the same label as the page is to be imaged. All expected dates of coverage from the time of launch to the end of June 1973 are listed from top to bottom on the left side of the catalogue page. The page is ruled into columns with headings designating various photo-products and other notations along the top. As photo-products are received, entries are made noting the number of copies and spectral bands in the appropriate column for the particular product, against the appropriate date along the left hand side. If for any reason an image scheduled to be taken on a particular date is not available; e.g., because of poor quality due to excessive cloud cover, the fact is so noted on the catalogue sheet against the appropriate date.

A copy of the mapsheet and sample catalogue sheet are attached.

This file system has proved to be the most efficient and systematic method of handling photo-products received at UCONN.

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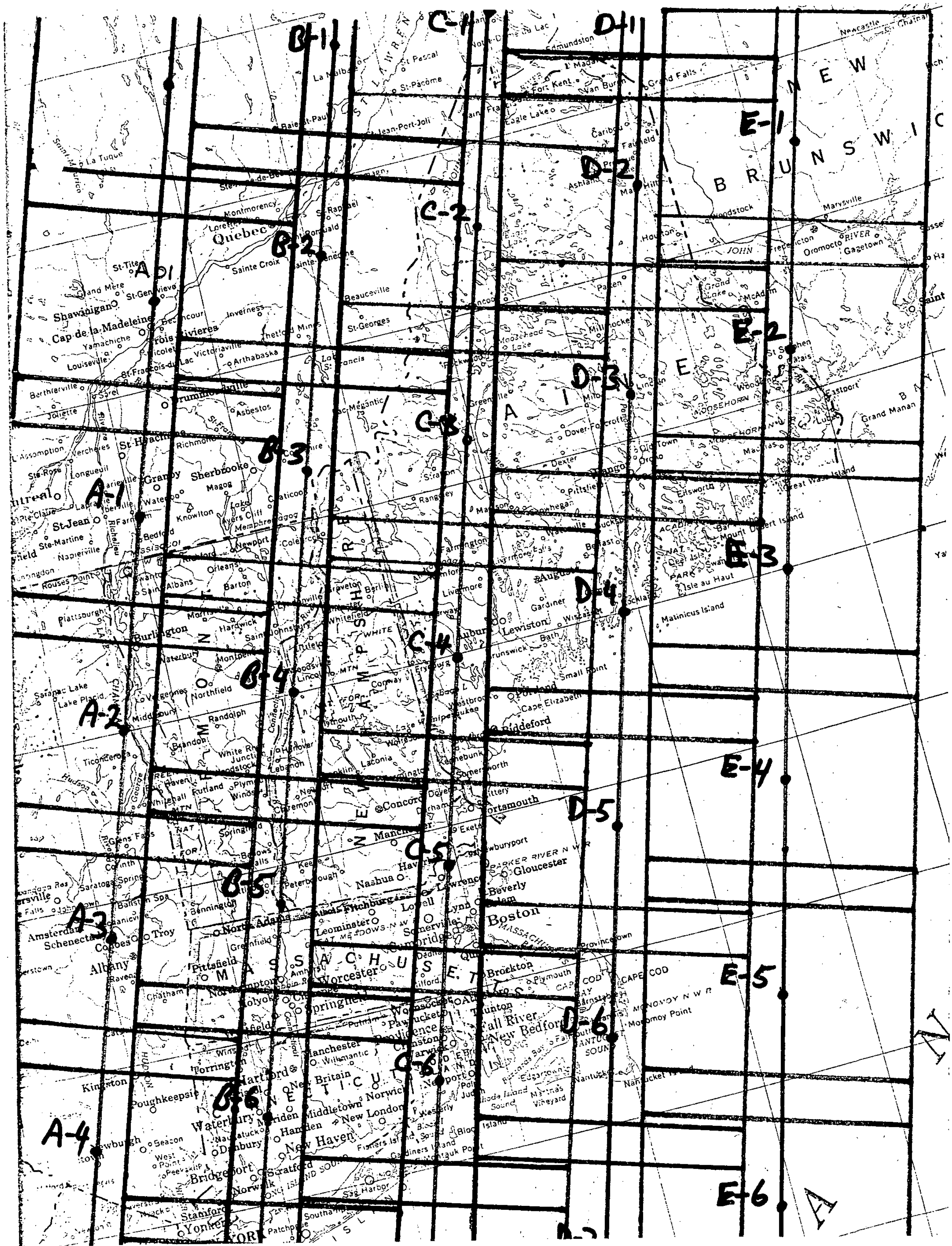
A-1
A-2
A-3
A-4
B-1
B-2
B-3
B-4
B-5
B-6
C-1
C-2
C-3
C-4
C-5
C-6
D-1
D-2
D-3
D-4
D-5
D-6
E-1
E-2
E-3
E-4
E-5
E-6
NEW BRUNSWICK
MAINE
NEW HAMPSHIRE
MASSACHUSETTS
CONNECTICUT
Quebec
Shawinigan
Cap-de-la-Madeleine
Sherbrooke
St Jean
Burlington
Montreal
Albany
Schenectady
Troy
Pittsfield
Worcester
Springfield
Hartford
New Britain
Waterbury
Meriden
Middletown
New Haven
New London
Norwich
Bridgeport
Stamford
Yonkers
Poughkeepsie
Kingston
Newburgh
Concord
Portsmouth
Manchester
Nashua
Lowell
Lawrence
Haverhill
Gloucester
Beverly
Boston
Somerville
Cambridge
Brockton
Fall River
New Bedford
Providence
Pawtucket
Taunton
Newport
Biddeford
Portland
Lewiston
Auburn
Augusta
Bangor
Edmundston
Fredericton
Woodstock
Eastport
Grand Manan
Nantucket
Martha's Vineyard
Cape Cod
Provincetown
Fitchburg
Leominster
North Adams
Bennington
Rutland
Montpelier
Barre
Plattsburgh
Ticonderoga

SAMPLE IMAGERY CATALOGUE SHEET

| Date of Orbit | Image ID # | 70mm(-) | 70mm(+) | 9.5 (T) | 9.5 (P) | Remarks | Borrowed |
|---|---|---|---|---|---|---|---|
| 29 Jul 72 | 1006-15061 | MSS 4-7 | | RBV 1-3<br>1 extra<br>RBV 1 | RBV 1-3<br>1 extra<br>RBV 3 | | |
| 16 Aug 72 | 1024-15062 | | | MSS 4-7 | MSS 4-7 | | |
| 3 Sep 72 | | | | | | | |
| 21 Sep 72 | 1060-15062 | MSS 4-7 | | MSS 4-7 | MSS 4-7 | | |
| 9 Oct 72 | 1078-15063 | MSS 4-7 | | MSS 4-7 | MSS 4-7 | | |
| 27 Oct 72 | 1096-15065 | MSS 4,6,7 | | MSS 4-6 | MSS 4-7 | | |
| 14 Nov 72 | | | | | | | |
| 2 Dec 72 | | | | | | | |
| 20 Dec 72 | | | | | | | |
| 7 Jan 73 | | | | | | | |

# Appendix B

## RBV Print Program

The program prints sections of RBV pictures (sets of digitized points) according to either a counting scale of 0 to 15 (hexadecimal code 0 thru 9 and A.B.C.D.E.F) or a pseudo-gray scale of 5 levels (blank, -, =, /, and #). It is difficult to distinguish more levels by eye without restricting characters, which would be very costly.

Since scene data and quarter of scene desired are determined by choice of tape (to be mounted), this information must be given in advance (not input to program). As of now there is one RBV scene available, 1006-15063. . .(6th day of mission; 3:06 p.m. and 30 seconds).

Inputs to the program are band choice (RBV 1, 2, 3), left and right endpoints, and top and bottom endpoints. The full quarter picture is 1152 points wide by 4125 lines long. If more than 128 points are desired across, the picture is scaled and the desired points are averaged into 128 points for printing. Averaging also takes place over an equivalent number of lines to preserve the (approximate) 1:4 ratio. Each line always prints 128, and as many lines as necessary (according to the scaling) are printed. If the entire (quarter) picture is printed, there are 458 lines.

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January 1973

SUMMARY OF INVESTIGATION #MMC 89:
THE USE OF ERTS IMAGERY IN RESERVOIR
MANAGEMENT AND OPERATION

CO-PRINCIPAL INVESTIGATORS:
MR. SAUL COOPER
DR. PAUL BOCK

FOR DISCIPLINE 4: WATER RESOURCES

Studies at the New England Division, Corps of Engineers, are focused on evaluating the possible usefulness of ERTS DCS and imagery to its watershed management functions. The first six months of ERTS-1 have been devoted primarily to installing and debugging equipment and general familiarization with ERTS data products, both DCS and imagery. To date, 17 of a planned 27 data collection platforms have been installed and are reporting to NED various hydrometeorological parameters on a near real-time basis via a direct teletype link with Goddard Space Flight Center. Only a very preliminary study of the data has been made so far. Statistical tests will be applied as soon as the data bank is of sufficient proportion. This should be within a few months as installation of the remaining DCP's is expected to be accomplished by early spring. Our imagery studies are centering on both photo-interpretation and computer-oriented analyses for depictions of useful hydrologic features. Preliminary work has suggested that configuration and areal coverage of surface waters, as well as other hydrologically related terrain features, may be obtained from ERTS imagery to an extent that would be useful to NED. Computer-oriented pattern recognition techniques are being developed to help automate the identification and analysis of hydrologic features in the imagery. Emphasis is made upon the need for close man-machine interaction while training the computer for these tasks.

January 1973

# SUMMARY OF INVESTIGATION #MMC 89: THE USE OF ERTS IMAGERY IN RESERVOIR MANAGEMENT AND OPERATION

CO-PRINCIPAL INVESTIGATORS:
MR. SAUL COOPER
DR. PAUL BOCK

FOR SUBDISCIPLINE 9B: SENSOR TECHNOLOGY-DATA COLLECTION PLATFORMS

The Data Collection System operated by the New England Division, Corps of Engineers, Waltham, Massachusetts, is relaying hydrometeorological information (primarily river stage, precipitation and water quality parameters) on a near real-time basis to NED with the aid of a direct teletype link with Goddard Space Flight Center. We are evaluating the viability of DCS for relay of data for watershed management purposes and also using it to aid our determination of an optimal layout of data collection points for the regulation of a typical river basin. To date, 17 of a planned 27 DCP's have been installed. Only very preliminary analysis of the data has been made so far, pending establishment of a more complete network of DCP's (we expect to have all 27 in place by early spring).

We have found it expedient to install each DCP at NED and obtain satellite data before field deployment. In addition, a simple inexpensive field strength meter, obtained from G.E., has proved invaluable in field testing the equipment. The "Gel-Cell" batteries and the DCP's are still operating satisfactorily despite severe winter weather conditions. We have had considerably more difficulty with defective sensors and with the interfacing of sensors to DCP's.

Transfer of data from NASA to NED has been good. Punchcards and printouts are received from NASA within a week after the acquisition of the data at GSFC. The near real-time teletype link with NASA has been functioning well, with about a 45-minute interval between ERTS-1 passover and data reception at NED.